Climate & Development Knowledge Network

Managing Climate Extremes and Disasters in the Agriculture Sector: Lessons from the IPCC SREX Report

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1. Introduction to SREX

1.1 About SREX

SREX on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) was commissioned by the Intergovernmental Panel on Climate Change (IPCC) in response to a recognised need to provide specific advice on climate change, extreme weather and climate events (‘climate extremes’). SREX was written over two and a half years, compiled by 220 expert authors, 19 review editors, and took account of almost 19,000 comments. It went through three rigorous drafting processes with expert and government review. The findings were approved by the world’s governments following a four-day meeting, where the Summary for Policy Makers was agreed. It thus provides the most complete scientific assessment available to date and describes the immediate and long-term action required to manage the risks we face. It comprises a policy summary released in November 2011 and the full report released in March 2012 (available online at http://ipcc-wg2.gov/srex).

This thematic brief summarises the key findings of the report relevant to the agriculture sector. It draws exclusively on material from SREX. It includes an assessment of the science and the implications for society, and sustainable development. It is intended to be useful for policy-makers, decision-takers and planners locally, nationally, and regionally. In recognition that these readers will have many competing calls on both their time and budgets, this brief seeks to highlight key thematic findings and learning from SREX. It makes suggestions for immediate action to avoid further damage and to build a more resilient future with benefits that go beyond agriculture.

Although not an official publication of the IPCC, this summary has been written under the supervision of co-authors of SREX and it has been thoroughly reviewed by an expert panel. The summary includes material directly taken from SREX, where the underlying source is clearly referenced, but it also presents synthesis messages that are the views of the authors of this summary and not necessarily those of the IPCC. It is hoped that the result will illuminate SREX’s vital findings for decision-makers working on agriculture issues, and so better equip them to make sound decisions about managing disaster risk in this context. This brief is one of four thematic briefs of SREX – on water, health, agriculture and ecosystems – that can be read individually or as a suite. There are also three regional SREX summaries for Africa, Asia, and Latin America and the Caribbean[1], which provide further information as a rapid reference source.

SREX considered the effects of climate change on extreme events, disasters, disaster risk reduction (DRR), and disaster risk management (DRM). It examined how climate extremes, human factors, and the environment interact to influence disaster impacts and risk management, and adaptation options (Figure 1). The report considered the role of development in exposure and vulnerability, the implications for disaster risk and DRM, and the interactions between extreme events, extreme impacts, and development. It examined how human responses to extreme events and disasters could contribute to adaptation objectives, and how adaptation to climate change could become better integrated with DRM practice. The report represents a significant step forward for the integration and harmonisation of the climate change adaptation (CCA), DRM, and climate science communities.

For agriculture sector policy-makers and planners, or indeed anyone whose work contributes to agricultural development, this brief should prompt discussion and understanding of several questions:

1. Why are extreme events a critical issue for agricultural development?
2. How is the agriculture sector affected by the risk and impact of extreme events?
3. What actions can be taken to manage these risks?

1.2 Ten key messages

Key overarching summary messages from SREX are[2]:

1. Even without taking climate change into account, disaster risk will continue to increase in many countries as more vulnerable people and assets are exposed to climate extremes. Extreme events have greater impacts on sectors that are closely linked with or dependent on the climate; agriculture is thus particularly exposed.

2. Based on data since 1950, evidence suggests that climate change has changed the magnitude and frequency of some climate extremes in some global regions already. For example, increasing dryness has been noted in some parts of Asia, particularly in East Asia, which can adversely affect agricultural and environmental conditions.

3. In the next two or three decades, the expected increase in climate extremes will probably be relatively small compared to the normal year-to-year variations in such extremes. However, as climate change becomes more dramatic, its effect on a range of climate extremes will become increasingly important, and will play a more significant role in disaster impacts.

1. http://cdkn.org/srex.
2. Highlights adapted from a note by Dr. Tom Mitchell, Overseas Development Institute and Dr. Maarten van Aalst, Red Cross/Red Crescent Climate Centre available at http://cdkn.org/srex.

4. There is better information on what is expected in terms of changes in extremes in various regions and sub-regions, rather than just globally, though for some regions and some extremes uncertainty remains high (e.g. precipitation trends across Africa, and drought trends across most of Asia).

5. High levels of vulnerability, combined with more severe and frequent weather and climate extremes, may result in some places being increasingly difficult places in which to live and work. The economies of many developing countries, for example, rely heavily on agriculture, dominated by small-scale and subsistence farming; livelihoods in this sector are especially exposed to climate extremes.

6. A new balance needs to be struck between measures to reduce risk, transfer risk (e.g. through insurance) and effectively prepare for and manage disaster impact in a changing climate. This balance will require a stronger emphasis on anticipation and risk reduction. An example is index based micro-insurance projects to help farmers to protect their assets and increase their productivity.

7. Existing risk management measures need to be improved as many countries are poorly adapted to current extremes and risks, so are not prepared for the future. This would include a wide range of measures such as technology-based early warning systems, land use planning, ecosystem management, and innovative and sustainable farming techniques that incorporate local knowledge systems.

8. Countries' capacity to meet the challenges of observed and projected trends in disaster risk is determined by the effectiveness of their national risk management system. Such systems include national and sub-national governments, the private sector, research bodies, and civil society including community-based organisations. The National Climate Risk Management Strategy and Action Plan in Mongolia, for example, seeks to build climate resilience at the community level through reducing risk, and facilitating adaptation.

9. More fundamental adjustments are required to avoid the worst disaster losses and tipping points where vulnerability and exposure are high, capacity is low, and weather extremes are changing. Many developing countries are facing impacts now, yet also have the most vulnerable populations, in the greatest number, who are least able to adapt.

10. Any delay in greenhouse gas mitigation is likely to lead to more severe and frequent climate extremes in the future and will likely further contribute to disaster losses. The agriculture sector is a high emitter of methane and nitrous oxide, for example, through livestock and fertilisation.

1.3 What does this mean for agriculture?

A changing climate leads to changes in the frequency, intensity, spatial extent, and duration of weather and climate events, and can result in unprecedented extremes, both through slow onset disasters (e.g. consecutive years of drought) and extreme events (e.g. heavy flooding). Many such events will have a direct impact on agricultural systems now and in the future, including through increased length, frequency and/or intensity of heatwaves, increased frequency of heavy precipitation in many regions, intensified droughts across some areas, upward trends in extreme coastal high water levels, and changes in flood patterns. Crops, livestock, and people will all be affected.

The agriculture sector is amongst those sectors most vulnerable to the impacts of climate change and weather extremes, not least because of its dependence upon natural resources such as water and ecosystem services. Water supply for agricultural production, for example, will be critical to sustain production, and even more important to provide the increase in food production required to sustain the world's growing population.

Transformational approaches are required in the management of natural resources, including new climate-smart agriculture policies, practices, and tools, better use of climate science information in assessing risks and vulnerability, and increased financing for food security. Planners and policy-makers have a key role to play in creating a conducive policy environment and securing financing for such transformation.

'Low regrets' adaptation options typically include improvements to coping strategies (i.e. strategies to overcome adverse conditions and restore basic functionality in the short to medium-term), or reductions in exposure to known future threats, such as better forecasting and warning systems, and the use of climate information to better manage agriculture in drought-prone regions. Other short-term adaptation strategies include diversifying livelihoods to spread risk, farming in different ecological niches, and risk pooling at the regional or national level to reduce financial exposure. Longer-term strategies include land rehabilitation, terracing and reforestation, measures to enhance water catchment and irrigation techniques, and the introduction of drought-resistant crop varieties.

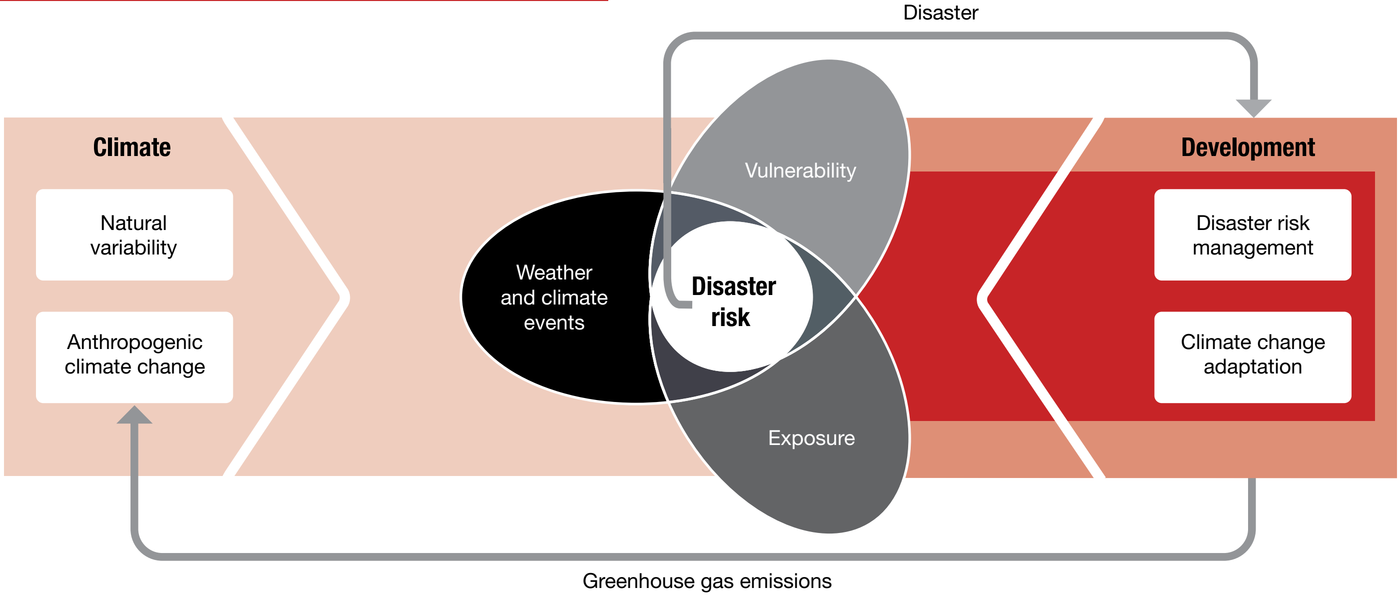
In moving forwards, there is a need for new and better disaster risk assessments that take climate change into account, which may require countries and people to reassess their thinking on what levels of risk they are willing and able to accept. It will also be important to strengthen new and existing partnerships for reducing risk, for example by including the private sector, and bilateral and multilateral agencies in decision-making and risk management processes. Furthermore, given the critical links between agriculture and other sectors such as water and infrastructure, it will be important to highlight changing climate-related disaster risks to policy-makers working in other policy domains.

Finally, there must be consideration that, in some cases, today's climate extremes will be tomorrow's 'normal' weather. Tomorrow's climate extremes may therefore stretch our imagination and challenge our capacity to manage change as never before.

2. Changing disaster risks

This section looks at the components of changing disaster risk in more detail. The inter-linkages between the core concepts discussed in SREX are illustrated in Figure 1. This shows how both changes in vulnerability and exposure, and changes in weather and extreme climate events, can contribute and combine to create disaster risk, hence the need for both DRM and CCA within development processes.

Figure 1: The inter-linkages between the core concepts of SREX



2.1 Changes in extreme events[3]

A changing climate leads to changes in the frequency, intensity, spatial extent, and duration of weather and climate extremes, and can result in unprecedented extremes. 'An *extreme (weather or climate) event* is generally defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends ('tails') of the range of observed values of the variable[4]'.

Many of the projected increases in extreme weather and climate events will have substantial impacts on agriculture. Some of the trends most relevant to agriculture include[5]:

- Observations since 1950 show changes in some extreme events, particularly daily temperature extremes, and heat waves.
- It is likely that the frequency of heavy precipitation will increase in the 21st century over many regions.
- Projected precipitation and temperature changes imply changes in flood patterns.
- There is evidence (medium confidence) that droughts will intensify over the coming century in southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa[6].
- It is very likely that average sea level rise will contribute to upward trends in extreme coastal high water levels.

CDKN has extracted region-specific data from SREX to provide an easy-to-use guide to future climate extremes in Africa, Asia, and Latin America and the Caribbean, respectively. These are included in Annex II.

3. Draws on material from SREX Chapter 3, Nicholls. N. et al, 'Changes in Climate Extremes and their Impacts on the Natural Physical Environment' and Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems'.
4. SREX Section 3.1.2 has a full explanation.
5. See Annex IV: IPCC uncertainty guidance, which shows the probabilities attached to particular terms such as 'likely' or 'very likely'.
6. Confidence is limited because of definitional issues regarding how to classify and measure a drought, a lack of observational data, and the inability of models to include all the factors that influence droughts.

2.2 Disaster risk, vulnerability, and exposure[7]

Impacts of extreme and non-extreme weather and climate events depend strongly on levels of vulnerability and exposure. Vulnerability and exposure are dynamic and depend on economic, social, demographic, cultural, institutional, and governance factors. Individuals and communities are therefore differentially exposed based on factors such as wealth, education, gender, age, class/caste, and health.

Exposure is a necessary but not sufficient condition for impacts. For exposed areas to be subjected to significant impacts from a weather or climate event, there must be vulnerability. Vulnerability is composed of:

- susceptibility of what is exposed to harm (loss or damage) from the event; and
- its capacity to recover.

So vulnerability is the propensity or predisposition of an exposed population to be adversely affected by weather or climate events.

Therefore lack of resilience and capacity to anticipate, cope with, and adapt to extremes are important factors of vulnerability in the agriculture sector.

Different development pathways can also make current and future populations more or less vulnerable to weather and climate events. High vulnerability and exposure are generally the outcome of skewed development, for example, environmental mismanagement, rapid and unplanned urbanisation, failed governance, and limited livelihood options.

Box 1: What climate science tells decision-makers – climate smart DRM is a top priority

Variability is always important. Climate trends are usually only one factor in the probability of hazards. In some regions and for some decisions, seasonal variability may be more important than long-term trends.

For decisions affecting just the next decade, it may be more important to think about what has changed already and what the near-term range of variability is, rather than what will happen in the coming century.

We know that uncertainty is increasing. There are some hints of future trends or ranges of uncertainty – but there is seldom specific information on precise future probabilities of particular extremes.

The quality of available information will differ between global, regional, and local scales.

There will be differences in what science can say about extremes. For example, the link between rising temperatures and heat waves is relatively robust; similarly the link between sea-level rise and high sea-level events is fairly straightforward. However, for some other extremes, such as tropical cyclones, trends are less directly related to well-predicted changes in average conditions.

These factors should be considered when reviewing climate science for decision and policy-making. However, uncertainty should not be used as a reason for inaction – investments must be made to reduce vulnerability and exposure. SREX provides enough information to show that more people and assets are in harm's way and much more can be done to reduce exposure, vulnerability, and risk.

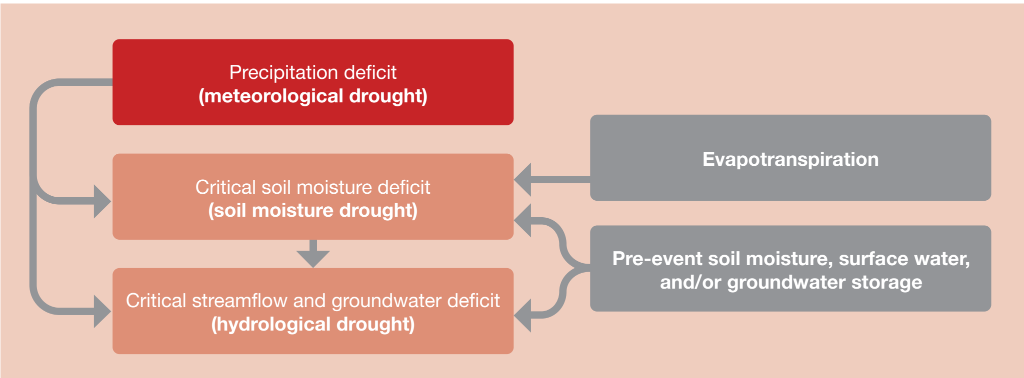
2.3 Consequences of variations in water supply[8]

This section builds on the information presented in this report so far, and highlights how extreme climate and weather-related events – such as droughts, floods, and temperature extremes – directly and indirectly impact on agricultural systems[9].

Drought can cause water shortages, crop failures, and starvation.

Soil moisture drought (also termed agricultural drought) during the growing season can result in a shortage of precipitation that impinges on crop production, or ecosystem function. Similarly, during the runoff and percolation season, a shortage of precipitation affects water supplies due to hydrological drought. Soil moisture deficits have several additional effects beside those on agro-ecosystems, most importantly on other natural or managed ecosystems (including both forests and pastures). These terms and their relationship are highlighted in Box 2 below.

Box 2: Types of drought and their inter-linkages



7. Draws on materials from SREX Chapter 2, Cardona, O.M. et al, 'Determinants of Risk: Exposure and Vulnerability' and SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.
8. Draws on material from SREX Chapter 1, Diop, C. et al, 'Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability and Resistance', SREX Chapter 3, Nicholls. N. et al, 'Changes in Climate Extremes and their Impacts on the Natural Physical Environment', SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.
9. Note that intermediary factors will also play a role in this impact, for example natural resource management, agricultural policy and enforcement (or lack of enforcement), and local practices. It is not within the remit of SREX to examine these intermediary factors in detail.

Soil moisture persistence is found to be an important component in projected changes in soil moisture drought, with some regions displaying year-round dryness compared to reference (late 20th century or pre-industrial) conditions due to the carry-over effect of soil moisture storage from season to season. In Asia for example, spatially varying trends have been observed during the second half of the 20th century, with increasing dryness noted in some areas, particularly in East Asia, adversely affecting socio-economic, agricultural, and environmental conditions.

Some projections on dryness, looking at changes in the number of consecutive dry days and at soil moisture anomalies for the periods 2046 to 2065 and 2081 to 2100, show that dryness is expected to increase across large parts of southern Europe, Africa, Latin America, and South East Asia by the end of the 21st century. Dryness is expected to decrease across the northern most parts of the US, Europe, and Asia, with some decreased dryness also projected for Central Asia, and parts of East Africa.

In the US, from 2000 to 2007 (excluding 2003), crop losses accounted for nearly all direct damages resulting from droughts. Droughts in Africa have also impacted agriculture, with substantial economic losses and famine recorded since the 1960s. People who live in drought-prone areas in Africa are vulnerable to the direct impacts of drought, including the death of cattle, and soil salinisation. Box 3 provides a further example of the impacts of drought on agriculture in Asia.

Flooding and heavy precipitation can have both positive and negative impacts on agricultural systems and productivity. Heavy precipitation and field flooding, for example, can delay spring planting, increase soil compaction, and cause crop losses through anoxia, and root diseases. Variation in precipitation is therefore responsible for the majority of the crop losses.

In the American Midwest in 1993, heavy precipitation flooded 8.2 million acres of soybean and cornfields, decreasing corn yields by 50% in Iowa, Minnesota, and Missouri, and by 20 to 30% in Illinois, Indiana, and Wisconsin. The Mozambique floods in 2000 also had a devastating effect on livelihoods, destroying agricultural crops, disrupting electricity supplies, and demolishing basic infrastructure.

However, flood-inducing rains can also have beneficial effects on the following season's crops, for example, to achieve the benefits of fertilisation from inundation agriculture in Cambodia, wide areas along the rivers need to be flooded. Furthermore, intense rainfall accompanying monsoons and hurricanes can also bring great benefits to society and ecosystems; on many occasions helping to fill reservoirs, sustain seasonal agriculture, and alleviate summer dry conditions in arid zones.

Box 3: The impacts of drought on rice yields in Asia

Drought can cause yield variation; about 15% (23 million hectares) of Asian rice areas experience frequent yield loss due to drought. The problem is particularly pertinent to eastern India, where the area of drought-prone fields exceeds more than 10 million hectares. Water supply for agricultural production will therefore be critical to sustain production, and even more important to provide the increase in food production required to sustain the world's growing population.

2.4 Consequences of extreme temperatures

Extreme heat: There is evidence that current warming trends around the world have already begun to impact agriculture. Although overall production may not be falling, crop yields in some areas have already started to decline due to warmer conditions compared to the expected yields without warming. A recent evaluation also concluded that future growing season temperatures will be very likely to exceed the most extreme temperatures observed from 1900 to 2006, for both tropical and sub-tropical regions, with substantial potential implications for global food systems. Many crops, for example, are especially sensitive to extreme temperatures that occur just prior to or during the critical pollination phase of crop growth. More frequent hot days are also likely to increase heat stress on human farm workers, animals and plants.

Extreme heat can reduce the yield of grain crops such as corn and increase stress on livestock. During the European heatwave of 2003 the (uninsured) economic losses for the agriculture sector in the European Union were estimated at €13 billion.

A record drop in crop yield of 36% occurred in Italy for maize grown in the Po Valley, where extremely high temperatures prevailed. Extreme events after a crop is grown can also impact agricultural production, for example wildfires in Australia in 2009 destroyed almost 430,000 hectares of forests, crops, and pasture, and over 55 businesses.

Extreme temperatures can negatively impact grain yield and quality. In rice, high temperatures (>35°C) coupled with high humidity and low wind speed caused panicle[10] temperatures to be as much as 4°C higher than air temperature, inducing floret sterility. Rice yields can be reduced by 90% when night temperatures are increased from 27 to 32°C. High temperature events during grain-filling of wheat can also alter the protein content of the grain, and high temperatures during grain-filling has been identified as one of the most significant factors affecting both yield and flour quality in wheat.

Extreme cold: Mean global warming does not exclude the possibility of cooling in some regions and seasons. It has for instance been recently suggested that the decrease in sea ice caused by the mean warming could induce, although not systematically, more frequent cold winter extremes over northern continents. Also parts of central North America and the eastern United States present cooling trends in mean temperature and some temperature extremes in the spring to summer season in recent decades.

Dzud is a compound hazard occurring in Mongolia's cold dry climate that encompasses a range of climate extremes that take place at different times throughout the year, including drought, heavy snowfall, extreme cold, and windstorms. The combination of these climate extremes results in dzud which lasts all year round and causes dramatic socio-economic impacts, including significant loss of livestock, unemployment, poverty, and mass migration from rural to urban areas, giving rise to heavy pressure on infrastructure, and social and ecosystem services. Thus, the term implies both exposure to such combinations of extreme weather conditions and also the impacts thereof.

The dzud of 2009/2010 occurred as a result of the following weather and climate extremes. In the summer of 2009, Mongolia suffered drought conditions, which restricted haymaking and foraging for livestock. This was followed by rainfall at the end of November which became a sheet of ice, and in late December, 19 out of 21 provinces recorded temperatures below -40°C; this was followed by heavy and continuous snowfall in January and February 2010. By April 2010, 75,000 herder families had lost all or more than half their livestock.

10. The panicle, an inflorescence, is the terminal component of the rice tiller (a specialised grain bearing branch) that bears rice spikelets, which develop into grains.

3. Future impacts

Extreme events will have a broad range of impacts on the agriculture sector. These include changing productivity and livelihood patterns, economic losses, and impacts on infrastructure, markets, and food security. Collectively these impacts can have a significant adverse effect on people, communities, and systems. This section looks ahead to explore the range of possible future impacts for the agriculture sector.

3.1 Increasing economic losses – a global overview[11]

There is high confidence that economic losses from weather and climate-related disasters are increasing, albeit with large inter-annual variability. Costs arise due to the economic, social, and environmental impacts of a climate extreme or disaster. Annual accumulated estimates have ranged from a few billion to about US$ 200 billion (in 2010 dollars), with the highest value for 2005 (the year of Hurricane Katrina). Whilst measured economic losses from disasters are largest in developed countries, there is high confidence that fatality rates and economic losses as a proportion of GDP are higher in developing countries. Developing countries are recognised as facing the greater impacts and having the most vulnerable populations, in the greatest number, who are least able to adapt to changes in *inter alia* temperature, water resources, agricultural production, human health, and biodiversity. The UNFCCC estimated that additional financing of about US$ 41 billion would be needed for agriculture, water, health, and coastal-zone protection, most of which would be used in developing countries.

3.2 Specific impacts on the agriculture sector[12]

Extreme events have greater impacts on sectors that are closely linked with or dependent on the climate, for example agriculture and food security, water, forestry, health, and tourism. In the US, for example, the economic impact of the 1993 Mississippi flooding showed a disproportionate loss of wealth in states with a strong dependence on the agriculture sector compared to states that had a more diversified economy. The economies of many developing countries rely heavily on agriculture, dominated by small-scale and subsistence farming, and livelihoods in this sector are especially exposed to climate extremes.

In Africa, agriculture is the economic sector most vulnerable and exposed to climate extremes. It contributes approximately 50% to Africa's total export value, and approximately 21% of its total GDP. Sub-Saharan Africa (SSA) is extremely vulnerable to climate extremes. The combination of high exposure to drought as a result of limited irrigation, and the disproportionate impact that small shifts in temperature and rainfall can have on production (as a result of some plants in Africa growing close to their climatic limits), adds to this risk.

At a national level, climate impacts on Namibia's natural resources are projected to cause annual losses of 1 to 6% of GDP, from which livestock production, traditional agriculture, and fishing are expected to be hardest hit, with a combined loss of US$ 461 million to US$ 2.045 billion per year by 2050. In Cameroon, a country highly dependent on rain-fed agriculture, a 14% reduction in rainfall is projected to cause significant economic losses, of up to around US$ 4.65 billion.

Small island developing states, and particularly atoll countries, are also particularly vulnerable to climate change and may experience erosion, inundation, and saline intrusion, resulting in ecosystem disruption, and decreased agricultural productivity. This reinforces their vulnerability to extreme weather events. Rural communities in many world regions also face greater risks of livelihood loss resulting from flooding of low-lying coastal areas, water scarcity and drought, decline in agricultural yields and fisheries resources, and loss of biological resources. In southern Australia, for example, climate change may cause land-use change, as cropping could become non-viable at the dry margins if rainfall substantially decreases, even though yield increases from elevated CO_2 partly offset this effect.

11. Draws on material from SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems'.
12. Draws on material from SREX Chapter 2, Cardona, O.M. et al, 'Determinants of Risk: Exposure and Vulnerability', SREX Chapter 4, Handmer, J. et al, 'Changes in Impacts of Climate Extremes: Human Systems and Ecosystems', SREX Chapter 5, Cutter, S. et al, 'Managing the Risks from Climate Extremes at the Local Level' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.

Box 4: Examples of recent economic losses caused by climate extremes

In Mexico, in 2005, Hurricane Stan caused about US$ 2.2 billion worth of damage, 65% of which were direct losses, and 35% due to future impacts on agricultural production. About 70% of these damages were reported in the state of Chiapas, representing 5% of state GDP.

In Australia, damages due to droughts in 1982 to 1983, 1991 to 1995, and 2002 to 2003 were US$ 2.3 billion, US$ 3.8 billion, and US$ 7.6 billion, respectively. Droughts have a negative impact on water security in the Murray-Darling Basin in Australia, as it accounts for most of the water for irrigated crops and pastures in the country.

In New Zealand, the 1997 to 1998 El Niño resulted in severe drought conditions across large areas with losses estimated at NZD 750 million (2006 values) or 0.9% of GDP. Severe drought in two consecutive summers, 2007 to 2009, affected a large area of New Zealand and caused on-farm net income to drop by NZD 1.5 billion.

In Mozambique, flooding in 2000 resulted in the loss of 167,000 hectares of agricultural land with 277,000 hectares of crops destroyed. The World Bank estimates that total direct losses as a result of the floods amounted to US$ 273 million.

In Mongolia, the 2009/2010 dzud affected over 50% of all herders' households and their livestock. By April, 75,000 herder families had lost all or more than half their livestock. The 2010 annual livestock census counted mortality of 10.3 million adult animals, and as a result, GDP share of agriculture decreased by 16.8% compared with 2009.

Climate extremes are one of multiple drivers of food insecurity. Extreme climate and weather events can raise the risk of production shortfalls due to low crop yields, reduce growing seasons, and lead to changes in agricultural land use (e.g. reduced availability of arable land due to water shortages). This can impact food availability, and also our access to it, for example food shortages can raise the cost of food on the global market, and weather events such as flooding can cause damage to underdeveloped infrastructure, preventing the timely transportation of food.

The agricultural and rural sector is vital for food security and employment. In many developing countries, traditional agricultural practices (e.g. subsistence farming and nomadic and pastoral livestock herding) continue to provide employment and livelihoods for rural communities. People's livelihoods in this sector are especially exposed to weather extremes and subsistence farmers and herders can be severely impacted by climate and weather events. In Kenya, for example, nearly all households grow maize, but only 36% sell it, with 20% accounting for the majority of sales. The majority of households eat all that they produce. Although this vulnerability limits the capacity of both such farmers and their governments for recovery, it is important to recognise that complex adaptations have already been undertaken by many subsistence farmers to secure their livelihoods in such uncompromising environments.

Food security is therefore linked to our ability to adapt agricultural systems to extreme events. Increasing food security risks will require better political decision-making (e.g. on global consumption patterns, post harvest losses, and food waste), higher agricultural productivity, reduced production variability, and ultimately agricultural systems that are more resilient to disruptive events. This implies transformations in the way natural resources are managed, for example through new climate-smart-agriculture policies, practices, and tools, better use of climate science information in assessing risks and vulnerability, and increased financing for food security.

4. Managing the risks of climate extremes and disasters[13]

This section considers the range of responses required in order to try to better manage the risks of climate extremes and disasters for the agriculture sector.

4.1 Developing strategies to support coping and adaptation

How well a community responds to and survives disaster depends upon the skills and resources that can be used to cope in the face of adverse conditions. Adaptation, a process of adjustment in anticipation of extreme events, can help to limit the 'coping' that may be required to survive the next disaster, whilst adaptive capacity focuses on longer-term and more sustained adjustments. As possible climate futures are uncertain, 'low regrets' adaptation strategies are often recommended, as these have net benefits over the range of anticipated future climate and associated impacts. Learning is also essential to risk management and adaptation. Research on learning emphasises the importance of action-oriented problem solving, learning-by-doing, and concrete learning cycles.

'Low regrets' adaptation options typically include improvements to coping strategies or reductions in exposure to known threats, such as better forecasting and warning systems, use of climate information to better manage agriculture in drought-prone regions, flood-proofing of homesteads, or interventions to ensure up-to-date climatic design information for engineering projects. Adaptation and DRM approaches for many development sectors benefit jointly from ecosystem-based adaptation and integrated land, water, and coastal zone management actions. For example, conservation and sustainable management of ecosystems, forests, land use, and biodiversity have the potential to create win-win disaster risk protection services for agriculture, infrastructure, cities, water resource management, and food security.

Other short-term but limited strategies to minimise food security risks include diversifying livelihoods to spread risk, farming in different ecological niches, building social networks, productive safety net and social protection schemes, and risk pooling at the regional or national level to reduce financial exposure. However, focusing on short-term responses and coping strategies can limit the scope for adaptation in the long-term. For example, drought can force agriculturalists to remove their children from school, or delay medical treatment, which may have immediate survival benefits, yet in aggregate undermines the human resources available for long-term adaptation. Specific longer-term strategies to address increasing risks, particularly given uncertainties, include land rehabilitation, terracing and reforestation, measures to enhance water catchment and irrigation techniques, improvements to infrastructure quality for better access to markets, and the introduction of drought-resistant crop varieties.

Investments in developing resilience to anticipate, absorb, and recover from climate shocks are usually primarily informed by information only over the expected lifetime of the investment, especially amongst poorer communities. For the decision of which crops to grow next season, some consideration may be given to longer-term strategies but the more pressing concern is likely to be the expected climate over the next season. Indeed, there is little point in preparing to survive the impacts of possible disasters a century beyond, if one is not equipped to survive more immediate threats. Thus, preparedness for climate change must involve preparedness for climate variability.

Disaster risks appear in the context of human choices that aim to satisfy human wants and needs, for example where to live, what crops to grow, and what infrastructure to support economic activities. In the context of natural hazards, the opportunity for changing is often greatest during the recovery phase, when physical infrastructure has to be rebuilt and can be improved, and behavioural patterns and habits can be contemplated. For example, in rethinking whether crops planted are the most suited to the climate.

A recent study suggests that adaptive capacity and livelihood resilience depend on a multi-level response to climate change, including social capital at the household level (e.g. education and other factors that enable individuals to function within a wider economy), the presence or absence of local enabling institutions (local cooperatives, banks, self-help groups), and the larger physical and social infrastructure that enables goods, information, services, and people to flow[14]. Interventions to catalyse effective adaptation are important at all these multiple levels, although this does not mean that interventions focused at only one of these levels cannot be effective in increasing resilience.

13. Draws on material from SREX Chapter 1, Diop, C. et al, 'Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability and Resistance' and SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters' and SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.
14. See Moench and Dixit, 2004.

4.2 Managing the risk at different scales/levels[15]

Increases in the occurrence of weather-related disaster risk will magnify the uneven distribution of impacts between wealthier and poorer countries. Climate change is already altering the geographical distribution, intensity, and frequency of these weather-related hazards, threatening to exceed the capacities of poorer countries to absorb losses and recover from disaster impacts. Moreover, disasters, once materialised, have ripple effects that often go well beyond the directly affected zones. So DRM becomes critical. This section considers the risk management options for agriculture at local, national and international levels.

Local level DRM[16]

Integrating local knowledge with additional scientific and technical knowledge can help to improve DRR and adaptation, both important elements of DRM. This self-generated knowledge can uncover existing capacity, as well as important shortcomings. Furthermore, the social organisation of individual societies dictates the flexibility in the choice of protective actions.

Disaster impacts vary by location, in who and what is at risk, the geographical extent of the potential impact and responses, and in stakeholders and decision-makers. Local populations who are vulnerable to climate extremes therefore have considerable experience with short-term coping responses, and adjustments to disaster risk, as well as with longer-term adjustments (or adaptations) such as the establishment of local flood defences and the selection of drought resistant crops. 'Early warnings' of potentially poor seasons have also informed key actions for agricultural planning on longer time scales and produced proactive responses.

Preparedness accepts the existence of residual, unmitigated risk, and attempts to aid society in eliminating some of the adverse effects that could be experienced, once a physical event occurs, for example by evacuating persons and livestock from exposed and vulnerable circumstances. Other practices that enhance resilience include crop improvement for drought tolerance, and adaptive agricultural practices. An example of the use of local knowledge and local action to support livelihoods and DRM is given in Box 5.

In many parts of Asia, adaptation to climate change, variability, and extreme events at the community level are small-scale and concentrate mainly on agriculture, water, and disaster amelioration. They focus on the livelihood of affected communities, raise awareness to change practices, diversify agriculture, and promote water conservation. In India, however, a combination of traditional and more innovative technological approaches are being used to manage drought risk. Technological drought management (e.g. development and use of drought tolerant cultivars, shifting cropping seasons in agriculture, and flood and drought control techniques in water management) is combined with model-based seasonal and annual to decadal forecasts. Model results are then translated into an early warning in order to take appropriate drought protection measures.

> Box 5: Local level DRM in Honduras: the role of Garifuna women
>
> **The Garifuna women have focused on livelihood-based activities to ensure food security by reviving and improving the production of traditional root crops, building up traditional methods of soil conservation, carrying out training in organic composting and pesticide use, and creating the first Garifuna farmers' market. In collaborative efforts, sixteen towns have now established tool banks, and five have seed banks. Through reforestation, the cultivation of medicinal and artisanal plants, and the planting of wild fruit trees along the coast, they are helping to prevent erosion, and reducing community vulnerability to hazards and the vagaries of climate.**

However, obstacles to utilising local knowledge as part of adaptation strategies exist. Climate-induced biodiversity change threatens historical coping strategies of indigenous people, as they depend on the variety of wild plants, crops, and their environments particularly in times of disaster. In dry land areas, such as in Namibia and Botswana, one of the indigenous strategies best adapted to frequent droughts is livestock herding, including nomadic pastoralism. Decreased access to water sources through fencing and privatisation has inhibited this strategy. In northern Kenya, social security networks existed among some groups of nomadic pastoralists that enabled food and livestock stock to be redistributed following drought events but these are also breaking down with the monetisation of the local economy among other factors.

To adapt to changing climate and weather extremes, difficult choices may become increasingly necessary. Adapting to scenarios of reduced water availability, for example, may involve increased investments in water infrastructure to provide enough irrigation to maintain existing agriculture production, or a shift from current production to less water consuming crops. Informal risk sharing practices are therefore common and important for post-disaster relief and reconstruction. In the absence of more formal mechanisms like insurance, those incurring losses may employ diverse non-insurance financial coping strategies such as traditional livestock loans in order to protect their assets and livelihoods.

The integration of local knowledge with external scientific, global, and technical knowledge is an important dimension of CCA and DRM. Experiences in environmental management and integrated assessment suggest mechanisms for such knowledge transfers both from the bottom up and from the top down. For example, in some communities trusted intermediaries have been set up to transfer and communicate external knowledge such as technology-based early warning systems, and innovative and sustainable farming techniques that incorporate the local knowledge system. Where such experiences and techniques are proving successful, stakeholders should be seeking to identify how these approaches might best be scaled up and replicated elsewhere.

15. Draws on materials from SREX Chapter 7, Burton, I. et al, 'Managing the Risks: International Level and Integration Across Scales' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.
16. Draws on materials from SREX Chapter 2, Cardona, O.M. et al, 'Determinants of Risk: Exposure and Vulnerability', SREX Chapter 5, Cutter, S. et al, 'Managing the Risks from Climate Extremes at the Local Level' and SREX Chapter 7, Burton, I. et al, 'Managing the Risks: International Level and Integration Across Scales'.

It will also be important to overcome the disconnect between local DRM and national institutional and legal policy and planning, for example by strengthening the coordination between inter-linked CCA and DRM activities locally that will in turn improve the implementation of national level plans. Such coordination can also avoid any negative impacts across different sectors or scales that could result from fragmented adaptation and development plans. Large-scale agriculture, irrigation and hydroelectric development interventions, for example, may benefit large groups or the national interests but may also harm local, indigenous and poor populations.

National level DRM[17]

National systems need to be at the core of countries' capacity to meet climate challenges. The UNFCCC commits parties (at 4.1(e)) to 'Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources, and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods.' However, greater efforts are required to address the underlying drivers of risk, and generate political will to invest in DRR. A set of features has been identified that make efforts to systematically manage disaster risk more successful. These are captured in Box 6.

Changes in weather and climate extremes pose new challenges for national DRM systems, which are often poorly adapted to the risks, although there are a few examples where mainstreaming adaptation to climate change and DRM issues have been priorities for many years and have made significant progress. For example, a coastal reforestation programme, including the planting in Sundarban, was initiated in Bangladesh in 1960, covering 159,000 hectares of the riverine coastal belt, and abandoned embankments.

Rehabilitation of agricultural livelihoods (e.g. the provision of seeds, planting material, fertilisers and stock, and the remediation of land) is particularly important where local livelihoods are directly affected such as in subsistence or semi-subsistence societies. However, in drought-ravaged northeastern Brazil, many vulnerable households could not take advantage of national risk management interventions such as seed distribution programs, because they lacked money to travel to pick up the seeds or could not afford a day's lost labour to participate.

The existing literature on legislation for adaptation at the state level is not comprehensive, although a number of countries studied lack many of the institutional mechanisms and legal frameworks important for coordination at this level. Without a supporting and implemented national legislative structure, achieving local DRR and CCA planning can be complicated. A helpful example on the powerful role of legislation is provided in Box 7.

Box 6: Features of successful national DRM systems[18]

- **Risks are recognised as dynamic and are mainstreamed and integrated into policy and strategy.**
- **Legislation for managing disaster risk is supported by clear regulation that is enforced.**
- **DRM functions are coordinated across sectors and scales and led by organisations at the highest political level.**
- **Risk is quantified and factored into national budgetary processes.**
- **Decisions are informed by the right information, using a range of tools and guidelines.**
- **Early warning systems are developed and linked to planning and policy-making.**
- **Responses cover hard infrastructure-based options as well as soft longer-term options building capacity and conservation measures.**

Box 7: The Role of Legislation in Mongolia[19]

The National Climate Risk Management Strategy and Action Plan (MMS 2009) in Mongolia seeks to build climate resilience at the community level through reducing risk, and facilitating adaptation by: i) improving access to water through region specific activities such as rainwater harvesting and creation of water pools from precipitation and flood waters, for use with animals, pastureland, and for crop irrigation purposes, ii) improving the quality of livestock by introducing local selective breeds with higher productivity and more resilience to climate impacts, iii) strengthening veterinarian services to reduce animal diseases/parasites, and cross-border epidemic infections, and iv) using traditional herding knowledge and techniques for adjusting animal types and herd structure, making them appropriate for the carrying capacity of the pastureland, and pastoral migration patterns. The formation of herders' community groups and the establishment of pasture co-management teams, along with better community based DRM could also facilitate effective DRR and CCA. At the national level the Mongolia CCA report outlines government strategy priorities as:

- ***education and awareness campaigns* among decision-makers, rural community, herders, and general public;**
- ***technology and information transfer* to farmers and herdsmen;**
- ***research and technology* to ensure the development of agriculture that could successfully deal with various environmental problems; and**
- ***improve coordination of stakeholders' activities* based on research, inventory, and monitoring findings.**

17. Draws on material from SREX Chapter 5, Cutter, S. et al, 'Managing the Risks from Climate Extremes at the Local Level', SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.
18. Draws on material from SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.
19. Draws on material from SREX Chapter 9, Murray, V. et al, 'Case Studies'.

Risk management at the international level and across sectors[20]

Increasing global interconnectivity, population and economic growth, and the mutual interdependence of economic and ecological systems can serve both to reduce vulnerability and to amplify disaster risks. International action on DRR and CCA is therefore motivated both by national interests and a concern for the common public good.

The international community has accumulated substantial experience in providing help for disasters and risk management in the context of localised and short-term events associated with climate variability and extremes, most commonly where needs have exceeded existing national capacity. The interdependence of the global economy, the public good, and the transboundary nature of risk management, and the potential of regional risk pooling, can make international cooperation on DRR and CCA more economically efficient than national or sub-national action alone.

International actors can also play a useful enabling role in DRM, and in promoting climate resilience, for example through risk sharing and transfer mechanisms, worldwide information exchange, and enabling access to insurance and other financial instruments to support CCA. The risk financing role of the international community is summarised in Box 8.

A good example of how the international community is supporting the development and financing of technology transfer for adaptation is the World Bank (2009) screening tool ADAPT (Assessment & Design for Adaptation to Climate Change: A Prototype Tool), a software based tool for assessing development projects for potential sensitivities to climate change. The tool combines climate databases and expert assessments of the threats and opportunities arising from climate variability and change. As of 2011, the knowledge areas covered include agriculture and irrigation in India and sub-Saharan Africa and, for all regions, various aspects of biodiversity, and natural resources.

The World Meteorological Organisation (WMO), the World Health Organisation (WHO), and the Food and Agriculture Organisation (FAO), amongst others, have also recognised that combinations of weather and climate hazards can result in complex emergency response situations. These organisations are therefore working to establish multi-hazard early warning systems for complex risks, for example early warnings of pests and food safety threats and disease outbreaks, e.g. for the prediction of a potential desert locust crisis.

Risk sharing (formal insurance, micro-insurance, and crop insurance) can be an effective tool for risk reduction and for recovering livelihoods after a disaster. Insurance can attract capital from international investors and can be used as an instrument for distributing disaster losses among a pool of at-risk households, farms, businesses and/or governments. It is the most recognised form of international risk transfer. Insurance can provide the necessary financial security to take on productive but risky investments. Many ongoing micro-insurance initiatives are index-based: a relatively new approach whereby the insurance contract is not against the loss itself, but against an event that causes loss, such as insufficient rainfall during critical stages of plant growth. Weather index insurance is largely at a pilot stage, with projects in Mongolia, Kenya, Malawi, Rwanda and Tanzania. Index insurance for agriculture is more developed in India, where the Agricultural Insurance Company of India (AIC) has extended coverage against inadequate rainfall to 700,000 farmers.

Index-based contracts as an alternative to traditional crop insurance have the advantages of greatly limiting transaction costs (from reduced claims handling), and improving emergency response. A disadvantage is their potential of a mismatch between yield and payout, a critical issue given the current lack of density of meteorological stations in vulnerable regions – a challenge remote sensing may help to address.

The international community is playing an active role in enabling insurance in developing countries. The World Bank and World Food Programme for example, provided essential technical assistance and support for the Malawi pilot micro-insurance program, which provides index-based drought insurance to smallholder farmers. With insurance, drought-exposed farmers in Malawi have been able to access improved seeds for higher yielding and higher risk crops thus helping them to leap ahead in terms of generating higher incomes, and the adoption of higher return technologies.

Box 8: The role of IFIs, donors and other international actors in climate risk financing

International agencies can play a catalytic role in the development of catastrophic risk financing solutions in vulnerable countries, most notably by:

- **exercising convening power and coordinating initiatives;**
- **supporting public goods for development of risk market infrastructure;**
- **providing technical assistance and sharing experience;**
- **creating enabling markets, for example in the banking sector; and**
- **financing risk transfer, for example through micro-insurance.**

20. Draws on materials from SREX Chapter 7, Burton, I. et al, 'Managing the Risks: International Level and Integration Across Scales' and SREX Chapter 9, Murray, V. et al, 'Case Studies'.

5. Conclusions: what does this mean for decision-makers in the Agriculture sector?

This final section considers the implications for agriculture policy and decision-makers in more detail. As climate change impacts become more severe, the effects on a range of climate extremes will become more important, and will play a more significant role in disaster impacts and DRM. The capacity to meet this challenge will be determined by the effectiveness of national risk management systems, including adaptation and mitigation measures.

Some countries are poorly prepared, and need to reassess their vulnerability, exposure, and investments in order to better manage disaster risks. A new balance needs to be struck between measures to reduce and transfer risk, and to effectively prepare for and manage disaster impacts in a changing climate.

5.1 Integrating DRM, CCA and sustainable development[21]

Sustainable development involves finding pathways that achieve a variety of socio-economic and environmental goals, without sacrificing any one for the sake of the others. Socio-economic and environmental dimensions are highly political, as are the relationships between adaptation, DRM, and sustainability. Successful reconciliation of multiple goals therefore `lies in answers to questions such as who is in control, who sets agendas, who allocates resources, who mediates disputes, and who sets the rules of the game[22]'.

Climate change is typically viewed as a slow-onset, multigenerational problem. Consequently, individuals, governments, and businesses have been slow to invest in adaptation measures. Research in South Asia, for example, shows that in those regions where past development had prioritised short-term gains over long-term resilience, agricultural productivity in some areas is in decline because of drought and groundwater depletion, rural indebtedness is increasing, and households are sliding into poverty with particularly insidious consequences for women, who face the brunt of nutritional deprivation as a result. Connecting short and long-term perspectives is thus seen as critical to realising the synergies between DRM and CCA that can contribute to a sustainable and resilient future.

There is a clear need for mainstreaming adaptation and DRM into existing national policies and plans, and for capitalising on options that take advantage of synergies with other national objectives. Studies found that many strategies and institutions were focused to a great extent on lower-risk actions dealing with science and outreach (knowledge acquisition), and capacity building rather than specific, more costly, and difficult to implement adaptation and DRM actions. Although there is no single approach, framework, or pathway to achieve this, some important contributing factors have been identified. These include reducing exposure, reducing vulnerability, transferring and sharing risks, and adequate preparation, response, and recovery. These are captured in Figure 2.

21. Draws on material from SREX Chapter 5, Cutter, S. et al, 'Managing the Risks from Climate Extremes at the Local Level' and SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.
22. Wilbanks, 1994.

Figure 2: Integrating adaptation and DRM approaches for a changing climate

Risks acceptance threshold

Reduce risks

Reduce vulnerability

- Poverty reduction.
- Health improvements.
- Access to services and productive assets enhanced.
- Livelihood diversification.
- Access to decision-making increased.
- Community security improved.

Reduce hazards and exposure

- Mainstream risk management into development processes.
- Building codes and retrofitting.
- Defensive infrastructure and environmental buffers.
- Land use planning.
- Catchment and other ecosystem management.
- Incentive mechanisms for individual actions to reduce exposure.

Pool, transfer and share risks

- Mutual and reserve funds.
- Financial insurance.
- Social networks and social capital.
- Alternative forms of risk transfer.

Manage residual risks and uncertainties

Prepare and respond effectively

- Early warning and communication.
- Evacuation plan.
- Humanitarian: relief supplies.
- Post-disaster livelihood support and recovery.

Increase capacity to cope with 'surprises'

- Flexibility in decision-making.
- Adaptive learning and management.
- Improved knowledge and skills.
- Systems transformation over time.

The effectiveness of actions to reduce, transfer, and respond to current levels of disaster risk could be vastly increased. Exploiting potential synergies between DRM and adaptation to climate change will contribute to social, economic, and environmental sustainability, helping to improve management of both current and future risks, and strengthen adaptation processes. DRM and adaptation to climate change literatures both now recognise the importance of bottom up, grass roots approaches, as well as emphasising the value of more holistic, integrated, trans-disciplinary approaches. In Syria, for example, the UN has been considering integrating CCA and DRR activities into its national Drought Response Plan, including drought risk loss insurance; adopting and adapting existing water harvesting techniques; developing crops tolerant to salinity and heat stress; changing cropping patterns; and capacity building of relevant stakeholders in vulnerable national and local areas.

Diversification within and beyond agriculture is also a widely recognised strategy for reducing risk and increasing well-being in many developing countries. Non-farm income now represents a substantial proportion of total income for many rural households previously dependent upon small scale farming and can, in turn, increase resilience to weather and climate related shocks. There is also a strong focus on systems innovation, and transformation of farming methods and socio-technical systems, with the potential of facilitating transitions from established systems, e.g. for agriculture, to alternative, sustainable systems. Technological development, for example, is one area in which a wide variety of new concepts that may eventually hold promise for DRR are being explored, e.g. through new food production technologies. However, technologies can have unintended consequences that contribute to maladaptations, for example, some modern agricultural technologies may reduce local biodiversity and constrain future adaptation.

In some circumstances, technologies put in place to reduce short-term risk and vulnerability can increase future vulnerability to extreme events or ongoing trends. For example, the use of irrigation has reduced farmer vulnerabilities to low and variable precipitation patterns, but when irrigation water is from a non-renewable source the foreseeable reduction in future irrigation opportunities would mean an increase in vulnerability, and the risk of increasing crop failures. Technology development and use are necessary for reducing vulnerabilities to climate extremes, both through mitigation and adaptation, but they need to be the right technologies developed in the right way and by the right people. This calls for greater reflection on the social, economic, and environmental consequences of technology across both space and time, and recognition that a number of ecological, ethical, and human health implications are often as yet unresolved. In many cases, responses to climate extremes can be improved by addressing social vulnerability, for example through strengthening institutions and policies, rather than focusing exclusively on technological responses.

5.2 Developing adaptation strategies: the importance of national systems[23]

Changes in weather and climate extremes pose new challenges for national DRM systems, which are often poorly adapted to the risks. The challenge for countries is to manage short-term climate variability while also ensuring that different sectors and systems become more resilient and adaptable to changing extremes and risks over the long-term. The requirement is to balance the short-term and the longer-term actions needed to resolve the underlying causes of vulnerability, and to understand the nature of changing climate hazards. Achieving adaptation and DRM objectives while attaining human development goals requires a number of cross-cutting, inter-linked sectoral and development processes, as well as effective strategies within sectors, and coordination between sectors.

Climate change is a cross-cutting and inter-linked issue and is thus far too big a challenge for any single ministry of a national government to undertake, for example in many countries climate change capacity has been focused in the Ministry of Environment, or DRR in the Ministry of Agriculture. Effective adaptation and risk reduction coordination between all sectors may only be realised if all areas of government are coordinated from the highest political and organisational level. National systems therefore need to be at the core of countries' capacity to meet climate challenges. Greater efforts are required to address the underlying drivers of risk and generate political will to invest in DRR and DRM and in CCA. South Africa's 2002 Disaster Management Act and its National Disaster Management Policy Framework of 2005 are noteworthy because they were among the first to focus on prevention, decentralise DRR governance, mandate the integration of DRR into development planning, and require stakeholder inclusiveness.

A range of possible measures at national level, from low-regrets to win-win, that address greenhouse gas reductions as well as adaptation and risk reduction, and which have broader developmental benefits have been identified in Table 1.

Table 1: Range of adaptation strategies at national level

'Low regrets' actions for current and future risks	('Low regrets' options plus…) Preparing for climate change risks by reducing uncertainties (building capacity)	('Preparing for climate change' risks plus...) Reduce risks from future climate change	Risk transfer	Accept and deal with increased and unavoidable (residual) risks	'Win-win' synergies for greenhouse gas reduction, adaptation, risk reduction, and development benefits
• Food security via sustainable land and water management, training; efficient water use, storage; agro-forestry; conservation agriculture; protection shelters, crop, and livestock diversification; improved supply of climate stress tolerant seeds; integrated pest, and disease management. • Climate monitoring; improved weather predictions; disaster management, crop yield and distribution models, and predictions.	• Increased agriculture-climate research and development. • Research on climate tolerant crops, livestock; agrobiodiversity for genetics. • Integration of climate change scenarios into national agronomic assessments. • Diversification of rural economies for climate sensitive agricultural practices.	• Adaptive agricultural and agroforestry practices for new climates, extremes. • New and enhanced agricultural weather, climate prediction services. • Food emergency planning; distribution and infrastructure networks. • Diversify rural economies.	• Improved access to crop, livestock, and income loss insurance (e.g. weather derivatives). • Micro-financing and micro-insurance. • Subsidies, and tax credits.	• Changed livelihoods and relocations in regions with climate-sensitive practices. • Secure emergency stock and improve distribution of food and water for emergencies.	• Energy efficient and sustainable carbon sequestering practices; training; reduced use of chemical fertilisers. • Use of bio-gas from agricultural waste and animal excreta. • Agroforestry.

23. Draws on material from SREX Chapter 6, Lal, P. N. et al, 'National Systems for Managing the Risks from Climate Extremes and Disasters'.

5.3 Building long-term resilience: from incremental to transformational approaches[24]

Extreme climate and weather events are predicted to increase significantly in coming decades. CCA and DRM are therefore likely to require not only *incremental (small, within existing technology and governance systems)* changes, but also *transformational (large, new system)* changes. This will involve moving away from a focus on issues and events towards a change in culture and overall approach. In Bangladesh, for example, a new Storm Warning Centre and associated coastal volunteer network was established as part of the country's early warning system.

For agriculture, transformational approaches include new climate-smart agriculture policies, practices and tools, better use of climate science information in assessing risks and vulnerability, and increased financing for food security. Planners and policy-makers must work together to create a conducive policy environment, and to secure financing for such transformation. Knowledge generation and testing of new approaches to support such transformations will also be critical.

5.4 Planning for an uncertain future[25]

In order to manage short-term climate variability whilst ensuring resilience and adaptation to changing extremes over the long-term, planners and policy-makers need to be aware of the misaligned priorities and competition that may exist between different stakeholders and sectors. Individual actors, for example, will have different needs and priorities to be met over varying timescales.

Among the most successful DRM and adaptation efforts are those that have facilitated the development of **partnerships** between local leaders and other stakeholders, including national and extra-local governments, and the private sector. This allows local knowledge, strengths and priorities to inform decision-making and risk management processes, while acknowledging that communities and local governments have limited resources and strategic scope to address the underlying drivers of risk on their own.

Leadership is also critical for DRM and CCA, particularly in initiating processes, and sustaining them over time. In order to implement a successful DRR or adaptation strategy, for example, clear legal and regulatory frameworks are beneficial in ensuring direction, coordination, and effective use of funds. The UNFCCC, for example, has been instrumental in helping Least Developed Countries to assess climate sensitive sectors (including agriculture) and prioritise projects to address urgent adaptations through the National Adaptation Programme of Action (NAPA) process.

Change processes are also shaped by the action of individual champions (including those resisting change), and their interactions with organisations, institutional structures, and systems. Leadership can be a driver of change, providing direction and motivating others to follow. Box 9, below, shows how international leadership has played a role in insurance for the agriculture sector. A number of private sector organisations have also demonstrated leadership at Chair and CEO level enabling transformational change within their organisations. National institutions and local governments could learn from these experiences.

Box 9: Partnerships, leadership and the role of international actors

Insurance and reinsurance markets attract capital from international investors, making insurance an instrument for transferring disaster risks over the globe. The market is highly international in character, yet uneven in its coverage. The international community is playing an active leadership role in enabling insurance in developing countries, particularly by supporting micro and sovereign (macro) insurance initiatives. This is resulting in new partnerships for the agriculture sector, for example:

- **The World Bank and World Food Programme (WFP) provided essential technical assistance and support for establishing the Malawi pilot micro-insurance program, which provides index-based drought insurance to smallholder farmers.**
- **The Mongolian government and World Bank support the Mongolian Index-Based Livestock Insurance Program by absorbing the losses from very infrequent extreme events (over 30% animal mortality), and providing a contingent debt arrangement to back this commitment.**
- **WFP successfully obtained an insurance contract through a Paris-based reinsurer to provide insurance to the Ethiopian government, which assures capital for relief efforts in the case of extreme drought.**

24. Draws on materials from SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.
25. Draws on materials from SREX Chapter 8, O'Brien, K. et al, 'Toward a Sustainable and Resilient Future'.

Some practical suggestions towards a more sustainable and resilient future

Investment: All stakeholders in the agriculture sector, including policy-makers, the farming community and wider civil society, and the private sector, should invest in:

- increasing knowledge around the potential risks and impacts of weather and climate extremes on agricultural systems and related sectors (e.g. water and infrastructure);
- developing accurate and timely early warning systems, and appropriate adaptation techniques and tools; and
- implementing preventive measures to reduce the risks, and subsequent impacts, of climate and weather extremes on agriculture.

Such preemptive investment will cost money now, but will save both money and lives in the future.

Research should underpin the above investment, helping stakeholders to strengthen the targeting and focus of their resources. Particular attention should be given to the integration of natural, social, economic, health, and engineering sciences, and their applications. With greater information available, it will be possible to better understand the risks to the agriculture sector, and ensure that response strategies are adequate to address them.

Empowerment: Drivers of hazard and vulnerability (e.g. social and political processes) need to be identified in ways that empower all stakeholders in the agriculture sector to take action. This is done best where local and scientific knowledge is combined in the generation of risk maps or risk management plans. Furthermore, given the critical links between agriculture and other sectors, such as water and infrastructure, better coordination and accountability is needed within governance hierarchies and across sectors, and between international actors where they are engaged. Helping individuals to become empowered lies at the core of transformational approaches to DRM, and CCA.

International actors must provide a coherent institutional framework to support experimentation, innovation, and flexibility, to finance risk transfer, and to support funding for adaptation. Where international agencies are required to balance their support to innovation against headquarters level requirements for risk avoidance, global best practice should be examined and adopted where applicable.

Technology must be considered an essential part of the response to climate extremes, at least partly, because technology choices and uses are so often a part of the problem. Enhancing early warning systems is one example where technology can play an important role in DRM, particularly in considering ‘hard’ (engineering) and ‘soft’ (social and administrative) technology. For the agriculture sector the range of possible ‘hard’ and ‘soft’ technologies include irrigation and crop rotation pattern, or the development of drought resistant crops.

Although technology is an essential part of the response to climate change, addressing social vulnerability and strengthening political decision-making processes are equally important. Climate change responses should not focus exclusively on technological approaches.

Transformational approaches must be considered by all stakeholders working to strengthen CCA and DRM for sustainable development. Whilst these can imply loss of the familiar, creating a sense of disequilibrium and uncertainty, transformations are already occurring at an unprecedented rate and scale, influenced by globalisation, social and technological development, and environmental change. Indeed, diversification within and beyond agriculture is a widely recognised strategy for reducing risk and increasing well-being in many developing countries. Climate change itself also represents a system-scale transformation that will have widespread consequences on the global economy, and on ecology and society, including through changes in climate extremes.

Transformation calls for leadership from authority figures who hold positions of power, and from individuals and groups who connect present-day actions with building a sustainable and resilient future.

For further information

The Summary for Policy Makers, full report, fact sheet and video is available at: www.ipcc-wg2.gov/srex.

Other useful links including videos and recommended reading are on the CDKN website here: www.cdkn.org/srex.

ANNEXES

Annex I: Acronyms

CBOs	Community Based Organisations
CCA	Climate Change Adaptation
CDKN	Climante and Development Knowledge Network
CSOs	Civil Society Organisations
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EM-DAT	Emergency Disasters Database
GCM	Global Climate Model
GDP	Gross Domestic Product
IFIs	International Financial Institutions
IPCC	Intergovernmental Panel on Climate Change
LDCs	Least Developed Countries
PTSD	Post-Traumatic Stress Disorder
SREX	SREX on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
UNFCCC	United Nations Framework Convention on Climate Change

Annex II: Changes in climate extremes

Key

Symbols

- Increasing trend
- Decreasing trend
- Varying trend
- Inconsistent trend/insufficient evidence
- No or only slight change

Level of confidence in findings

- Low confidence
- Medium confidence
- High confidence

Africa

SREX provides robust scientific information on what can be expected from changes in weather and climate extremes in various regions and sub-regions of Africa. A summary of this information is captured in Table 2 and 3.

Table 2: Observed changes in temperature and precipitation extremes since the 1950s[26]

Table 2 shows observed changes in temperature and precipitation extremes, including dryness in regions of Africa since 1950, with the period 1961 to 1990 used as a baseline (see Box 3.1 in Chapter 3 of SREX for more information).

Region and Sub-region	Trends in maximum temperature (warm and cold days)[27]	Trends in minimum temperature (warm and cold nights)[28]	Trends in heat waves/ warm spells[29]	Trends in heavy precipitation (rain, snow)[30]	Trends in dryness and drought[31]
West Africa	Significant increase in temperature of warmest day and coolest day in large parts Insufficient evidence in others	Increasing frequency of warm nights (decrease in cold nights in large parts) Insufficient evidence in others	Insufficient evidence for most of the region	Precipitation from heavy rainfall events decreased in many areas (low spatial coherence), rainfall intensity increased	Increased dry spell duration, greater inter-annual variation in recent years
East Africa	Lack of evidence due to lack of literature and spatially non-uniform trends	Spatially varying trends in most areas Increase in warm nights in southern tip (decrease in cold nights)	Insufficient evidence for most of the region	Insufficient evidence	Spatially varying trends in dryness
Southern Africa	Increase in warm days (decrease in cold days)	Increase in warm nights (decrease in cold nights)	Increase in warm spell duration	No spatially coherent patterns of trends in precipitation extremes	General increase in dryness
Sahara	Lack of literature	Increase in warm nights Lack of literature on trends in cold nights	Insufficient evidence	Insufficient evidence	Limited data, spatial variation of the trends

26. Period 1961 to 1990 used as a baseline.
27. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
28. Refers to the number of warm nights and cold nights with minimum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
29. Warm spell refers to periods of at least six days where maximum temperature values exceed the 90th percentile with respect to the 1961 to 1990 reference period.
30. Refers to the number of days with precipitation above an extreme value, e.g. the 90th percentile, with respect to the 1961 to 1990 reference period.
31. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index. Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Table 3: Projected changes in temperature and precipitation extremes, including dryness, in Africa

Table 3 shows projected changes in temperature and precipitation extremes, including dryness, in Africa. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[32] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[33]	Trends in minimum temperature (the frequency of warm and cold nights)[34]	Trends in heat waves/ warm spells[35]	Trends in heavy precipitation (rain, snow)[36]	Trends in dryness and drought[37]
West Africa	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Slight or no change in heavy precipitation indicators in most areas Low model agreement in northern areas	Inconsistent signal
East Africa	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Likely increase in heavy precipitation indicators	Decreasing dryness in large areas
Southern Africa	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Lack of agreement in signal for region as a whole Some evidence of increase in heavy precipitation in southeast regions	Increase in dryness, except eastern part Consistent increase in area of drought
Sahara	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Low agreement or no signal	Inconsistent signal of change

32. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
33. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
34. Refers to the number of warm nights and cold nights with temperature extremes above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
35. Warm spell refers to periods of at least six days where extreme temperature values exceed the 90th percentile in 2071 to 2100, with respect to the 1961 to 1990 reference period.
36. Refers to the number of days with precipitation above an extreme value, e.g. the 95th percentile, or above 10mm in one day in 2071 to 2100, with respect to the 1961 to 1990 reference period.
37. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Asia

SREX provides robust scientific information on what can be expected from changes in weather and climate extremes in various regions and sub-regions of Asia. A summary of this information is captured in Table 4 and 5.

Key

Symbols

- Increasing trend
- Decreasing trend
- Varying trend
- Inconsistent trend/insufficient evidence
- No or only slight change

Level of confidence in findings

- Low confidence
- Medium confidence
- High confidence

Table 4: Observed changes in temperature and precipitation extremes since the 1950s[38]

Table 4 shows observed changes in temperature and precipitation extremes, including dryness in regions of Asia since 1950, with the period 1961 to 1990 used as a baseline (see Box 3.1 in Chapter 3 of SREX for more information).

Region and Sub-region	Trends in maximum temperature (warm and cold days)[39]	Trends in minimum temperature (warm and cold nights)[40]	Trends in heat waves/ warm spells[41]	Trends in heavy precipitation (rain, snow)[42]	Trends in dryness and drought[43]
North Asia	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Spatially varying trends	Increase in some regions, but spatial variation	Spatially varying trends
Central Asia	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Increase in warm spells in a few areas Insufficient evidence in others	Spatially varying trends	Spatially varying trends
East Asia	Likely increase in warm days (decrease in cold days)	Increase in warm nights (decrease in cold nights)	Increase in heat waves in China Increase in warm spells in northern China, decrease in southern China	Spatially varying trends	Tendency for increased dryness
Southeast Asia	Increase in warm days (decrease in cold days) for northern areas Insufficient evidence for Malay Archipelago	Increase in warm nights (decrease in cold nights) for northern areas Insufficient evidence for Malay Archipelago	Insufficient evidence	Spatially varying trends, partial lack of evidence	Spatially varying trends
South Asia	Increase in warm days (decrease in cold days)	Increase in warm nights (decrease in cold nights)	Insufficient evidence	Mixed signal in India	Inconsistent signal for different studies and indices
Western Asia	Very likely increase in warm days (decrease in cold days more likely than not)	Likely increase in warm nights (decrease in cold nights)	Increase in warm spells	Decrease in heavy precipitation events	Lack of studies, mixed results
Tibetan Plateau	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Spatially varying trends	Insufficient evidence	Insufficient evidence. Tendency to decreased dryness

Table 5: Projected changes in temperature and precipitation extremes, including dryness, in Asia

Table 5 shows projected changes in temperature and precipitation extremes, including dryness, in Asia. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[44] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[45]	Trends in minimum temperature (the frequency of warm and cold nights)[46]	Trends in heat waves/ warm spells[47]	Trends in heavy precipitation (rain, snow)[48]	Trends in dryness and drought[49]
North Asia	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Likely increase in heavy precipitation for most regions	Inconsistent signal of change
Central Asia	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Inconsistent signal in models	Inconsistent signal of change
East Asia	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Increase in heavy precipitation across the region	Inconsistent signal of change
Southeast Asia	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells over continental areas Low confidence in changes for some areas	Inconsistent signal of change across most models (more frequent and intense heavy precipitation suggested over most regions)	Inconsistent signal of change
South Asia	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Slight or no increase in %DP10 index More frequent and intense heavy precipitation days over parts of S. Asia	Inconsistent signal of change
West Asia	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Inconsistent signal of change	Inconsistent signal of change
Tibetan Plateau	Likely increase in warm days (decrease in cold days)	Likely increase in warm nights (decrease in cold nights)	Likely more frequent and/or longer heat waves and warm spells	Increase in heavy precipitation	Inconsistent signal of change

38. Period 1961 to 1990 used as a baseline.
39. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
40. Refers to the number of warm nights and cold nights with minimum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
41. Warm spell refers to periods of at least six days where maximum temperature values exceed the 90th percentile with respect to the 1961 to 1990 reference period.
42. Refers to the number of days with precipitation above an extreme value, e.g. the 90th percentile, with respect to the 1961 to 1990 reference period.
43. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.
44. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
45. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
46. Refers to the number of warm nights and cold nights with temperature extremes above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
47. Warm spell refers to periods of at least six days where extreme temperature values exceed the 90th percentile in 2071 to 2100, with respect to the 1961 to 1990 reference period.
48. Refers to the number of days with precipitation above an extreme value, e.g. the 95th percentile, or above 10mm in one day in 2071 to 2100, with respect to the 1961 to 1990 reference period.
49. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Latin America and the Caribbean

SREX provides robust scientific information on what can be expected from changes in weather and climate extremes in various regions and sub-regions of Latin America and the Caribbean. A summary of this information is captured in Table 6 and 7.

Key

Symbols
- Increasing trend
- Decreasing trend
- Varying trend
- Inconsistent trend/insufficient evidence
- No or only slight change

Level of confidence in findings
- Low confidence
- Medium confidence
- High confidence

Table 6: Observed changes in temperature and precipitation extremes since the 1950s[50]

Table 6 shows observed changes in temperature and precipitation extremes, including dryness in regions of Latin America since 1950, with the period 1961 to 1990 used as a baseline (see Box 3.1 in Chapter 3 of SREX for more information).

Region and Sub-region	Trends in maximum temperature (warm and cold days)[51]	Trends in minimum temperature (warm and cold nights)[52]	Trends in the heat waves/warm spells[53]	Trends in heavy precipitation (rain, snow)[54]	Trends in dryness and drought[55]
Amazon	Insufficient evidence to identify a significant trend	Insufficient evidence to identify a significant trend	Insufficient evidence	Increase in many areas, decrease in a few areas	Decrease in dryness for much of the region. Some opposite trends and inconsistencies
Northeastern Brazil	Increase in warm days	Increase in warm nights	Insufficient evidence	Increase in many areas, decrease in a few areas	Varying and inconsistent trends
Southeastern South America	Spatially varying trends (increase in some areas decrease in others)	Increase in warm nights (decrease in cold nights)	Spatially varying trends (increase in some areas, decrease in others)	Increase in northern areas Insufficient evidence in southern areas	Varying and inconsistent trends
West Coast South America	Spatially varying trends (increase in some areas decrease in others)	Increase in warm nights (decrease in cold nights)	Insufficient evidence	Increase in some areas, decrease in others	Varying and inconsistent trends
Central America and Mexico	Increase in warm days (decrease in cold days)	Increase in warm nights (decrease in cold nights)	Spatially varying trends (increase in some areas, decrease in others)	Increase in many areas, decrease in few areas	Varying and inconsistent trends

50. Period 1961 to 1990 used as a baseline.
51. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
52. Refers to the number of warm nights and cold nights with minimum temperature above or below extreme values, e.g. the 90th/10th percentile with respect to the 1961 to 1990 reference period.
53. Warm spell refers to periods of at least six days where maximum temperature values exceed the 90th percentile with respect to the 1961 to 1990 reference period.
54. Refers to the number of days with precipitation above an extreme value, e.g. the 90th percentile, with respect to the 1961 to 1990 reference period.
55. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index. Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

Table 7: Projected changes in temperature and precipitation extremes at the end of 21st century[56]

Table 7 shows projected changes in temperature and precipitation extremes, including dryness in Latin America. The projections are for the period 2071 to 2100 (compared with 1961 to 1990) or 2080 to 2100 (compared with 1980 to 2000) and are based on GCM and RCM[57] outputs run under the A2/A1B emissions scenario.

Region and Sub-region	Trends in maximum temperature (the frequency of warm and cold days)[58]	Trends in minimum temperature (the frequency of warm and cold nights)[59]	Trends in the heat waves/warm spells[60]	Trends in heavy precipitation (rain, snow)[61]	Trends in dryness and drought[62]
Amazon	Likely increase in warm days (likely decrease in cold days)	Very likely increase in warm nights (likely decrease in cold nights)	Likely more frequent and longer heat waves and warm spells	Tendency for increases in heavy precipitation events	Inconsistent trends
Northeastern Brazil	Likely increase in warm days (likely decrease in cold days)	Likely increase in warm nights (likely decrease in cold nights)	Likely more frequent and longer heat waves and warm spells in some studies. Non-significant signal in others	Slight or no change	Increase in dryness
Southeastern South America	Likely increase in warm days (likely decrease in cold days)	Very likely increase in warm nights (likely decrease in cold nights)	Tendency for more frequent and longer heat waves and warm spells	Increases in northern areas Insufficient evidence in southern areas	Inconsistent trends
West Coast South America	Likely increase in warm days (likely decrease in cold days)	Likely increase in warm nights (likely decrease in cold nights)	Likely more frequent and longer heat waves and warm spells	Increases in tropics Insufficient evidence in extratropics	Varying and inconsistent trends
Central America and Mexico	Likely increase in warm days (likely decrease in cold days)	Likely increase in warm nights (likely decrease in cold nights)	Likely more frequent, longer and/or more intense heat waves/warm spells in most of the region	Inconsistent trends	Increase in dryness in Central America and Mexico, with less confidence in trend in extreme South of region

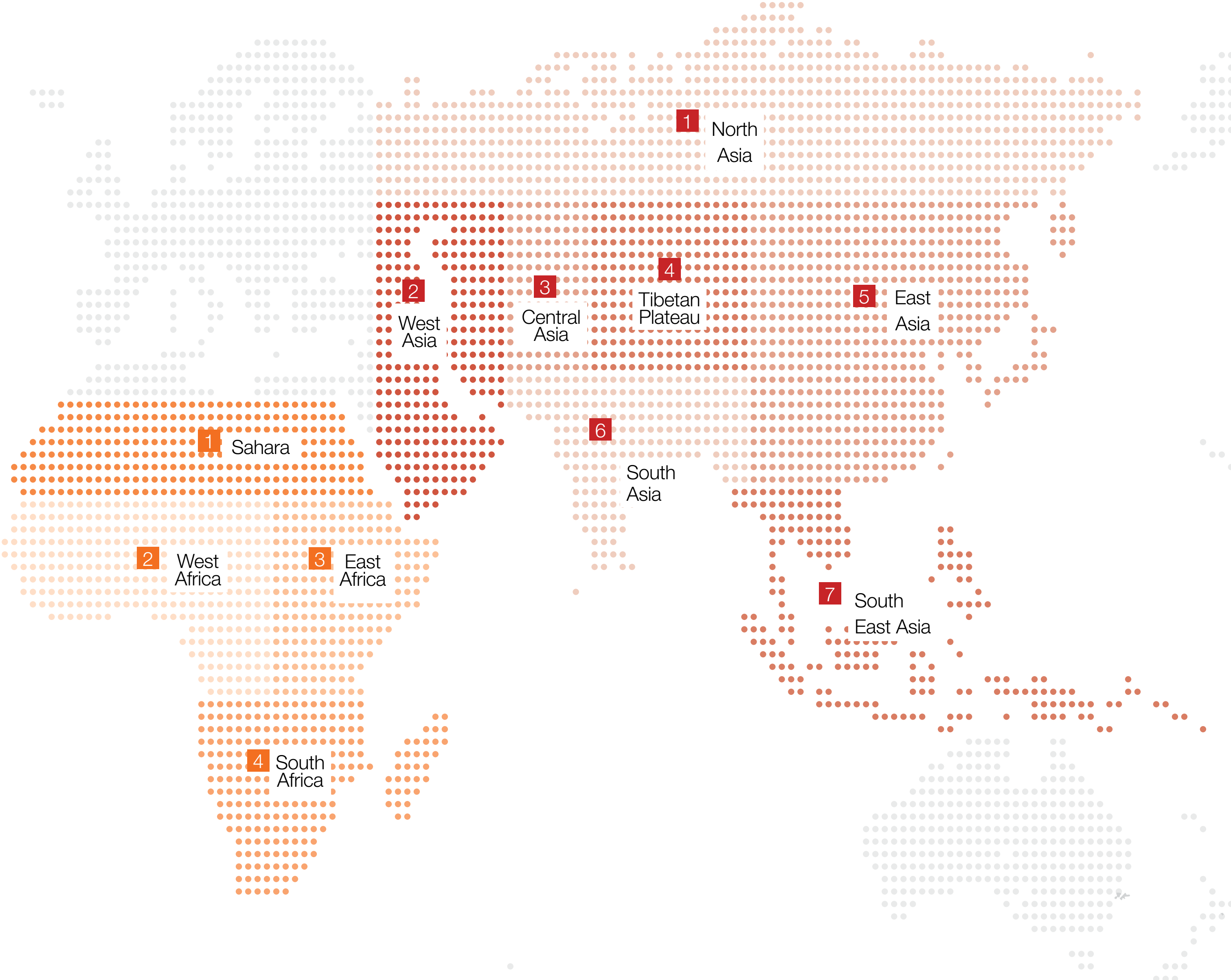
56. Projections are for the end of the 21st century vs end of the 20th century (e.g. 1961 to 1990 or 1980 to 2000 vs 2071 to 2100 or 2080 to 2100) and for the A2/A1B emissions scenario.
57. GCM refers to Global Circulation Model, RCM refers to Regional Climate Model.
58. Refers to the number of warm days and cold days with maximum temperature above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
59. Refers to the number of warm nights and cold nights with temperature extremes above or below extreme values, e.g. the 90th/10th percentile in 2071 to 2100 with respect to the 1961 to 1990 reference period.
60. Warm spell refers to periods of at least six days where extreme temperature values exceed the 90th percentile in 2071 to 2100, with respect to the 1961 to 1990 reference period.
61. Refers to the number of days with precipitation above an extreme value, e.g. the 95th percentile, or above 10mm in one day in 2071 to 2100, with respect to the 1961 to 1990 reference period.
62. Dryness is calculated in relation to a number of variables including: number of consecutive dry days (dry is defined as daily precipitation with <1mm); soil moisture anomalies; and drought severity index. Dryness refers to a hydro-meteorological water deficit, whereas drought is extended and continuous water shortage. More information is given in Box 3.3 of Chapter 3 in SREX.

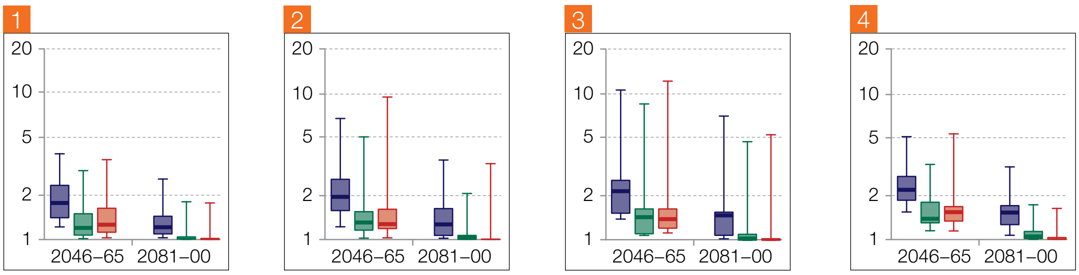
Annex III: Return period maps

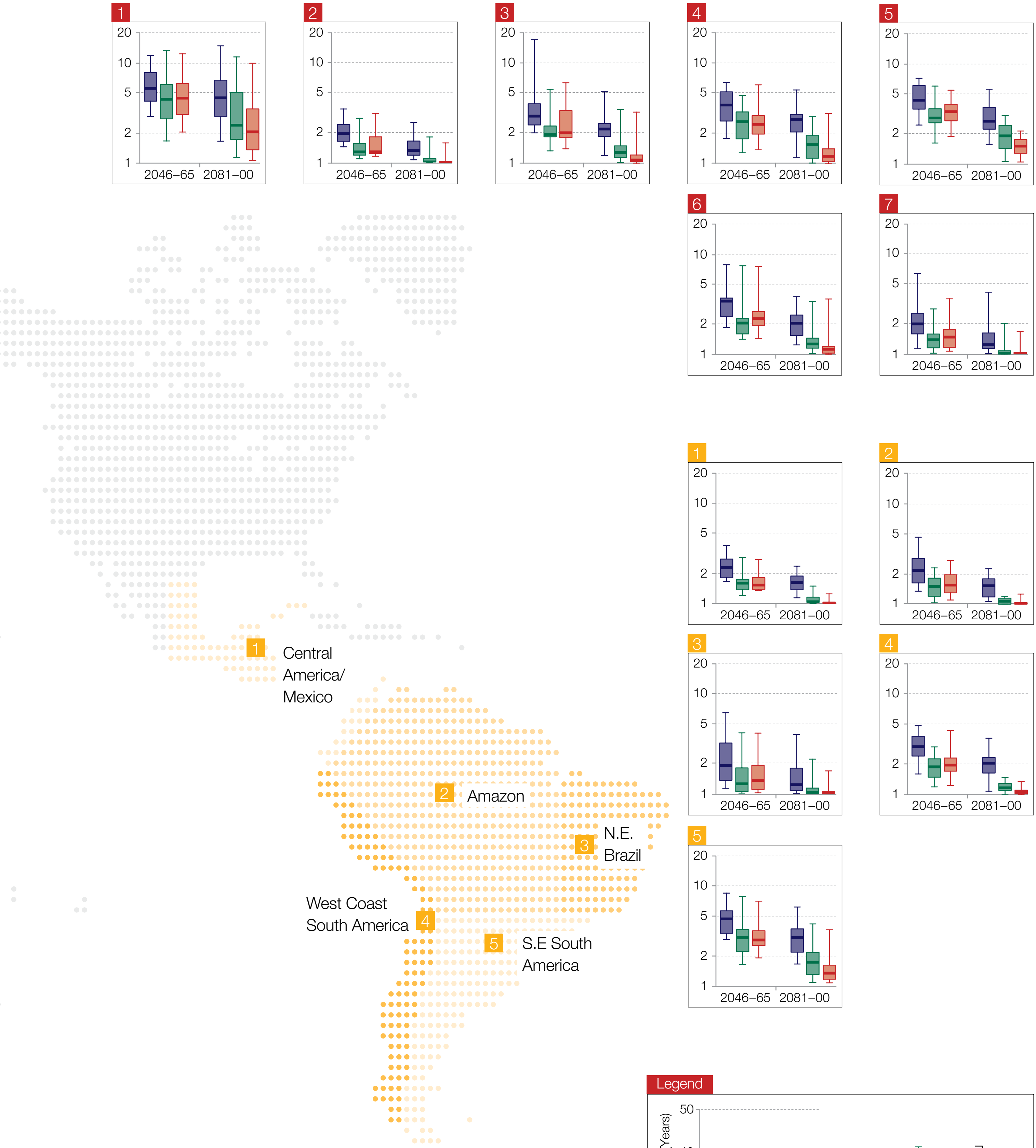
(a) Temperature

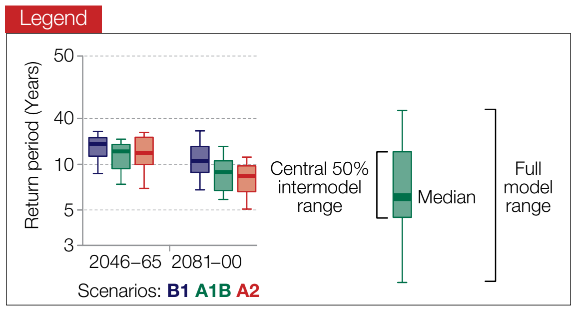
The temperature graph shows how often the hottest day in the last 20 years of the 20th century will be experienced by the middle and end of the 21st century. These are shown under three different emissions scenarios: B1, A1B and A2.[63]

For example the hottest day experienced in the last 20 years at the end of the 20th century will occur at least biannually by 2046-65 across africa and under both the A1B and A2 scenarios by 2100, every year, everywhere. What is now an extreme will become normal.





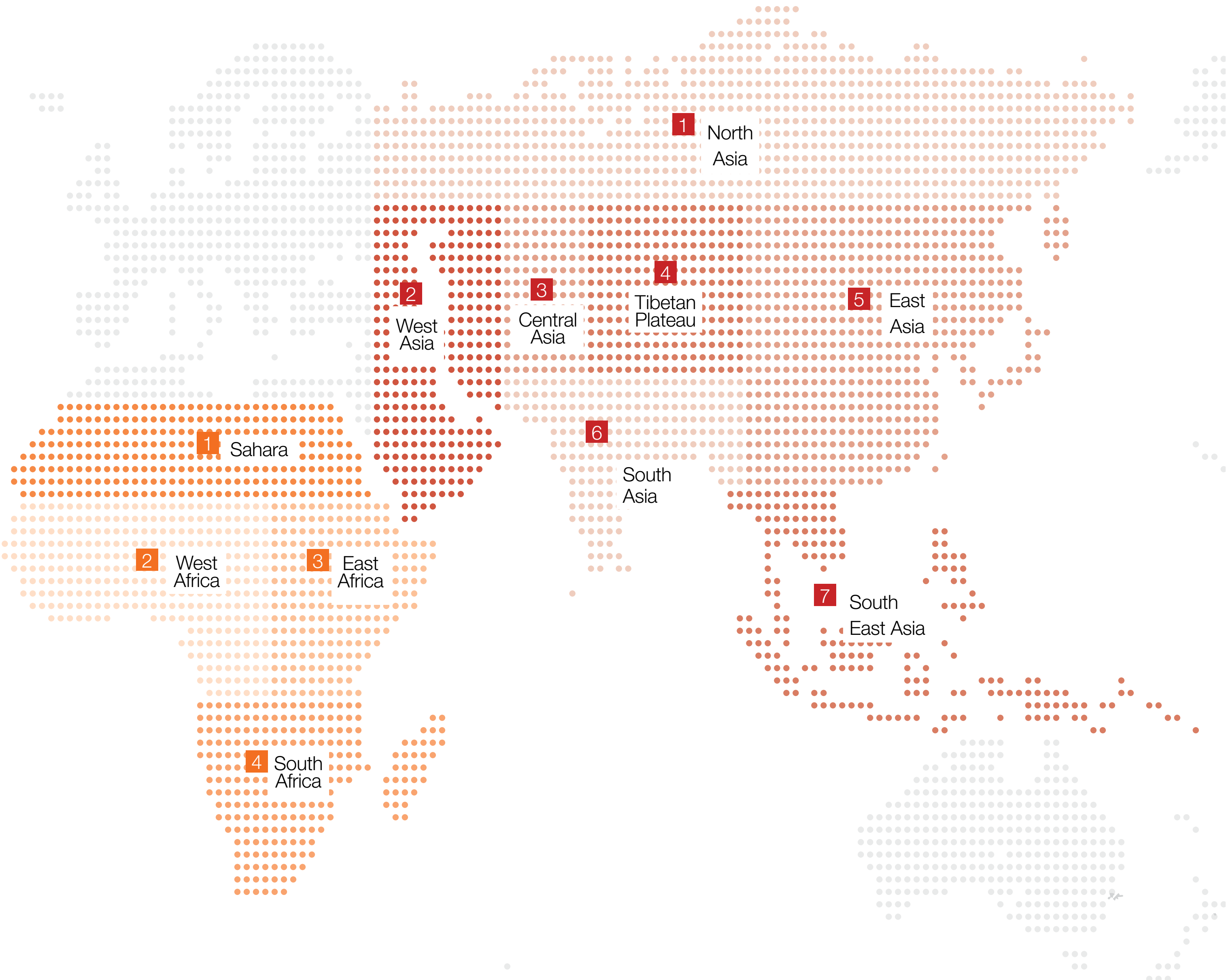


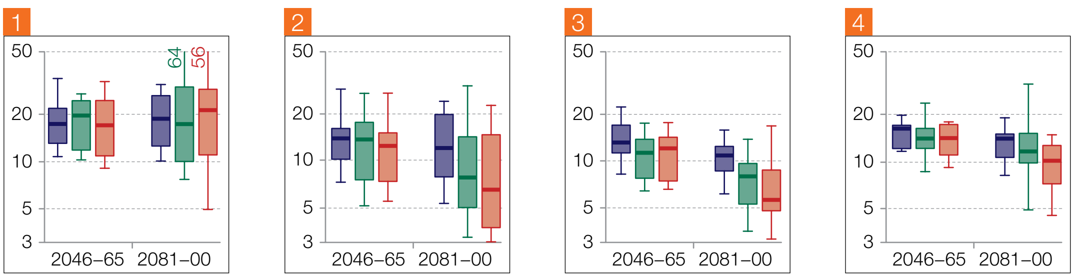


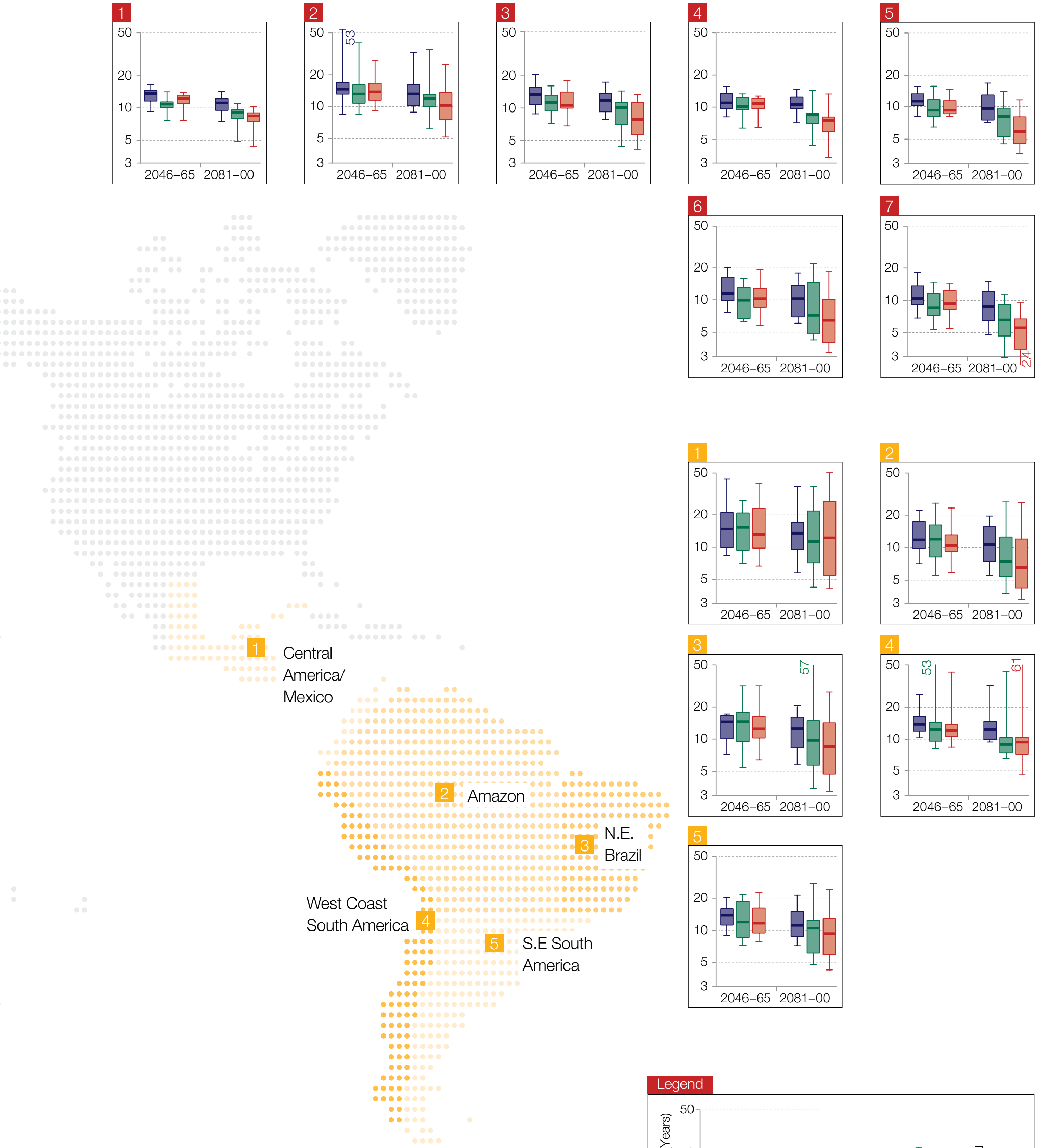
63. These refer to three of the six possible IPCC emissions scenario groups used throughout their reports.
B1 describes a convergent world with rapid changes towards a service and information economy and introduction of clean and resource efficient technologies.
A1B describes rapid economic development and growth, with balanced technological development across all sources, i.e. neither fossil intensive nor all non-fossil sources.
A2 is a heterogeneous world with self reliance and local identity, regional economic development, fragmented and slower growth.
See www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf Figure 1 for more information.

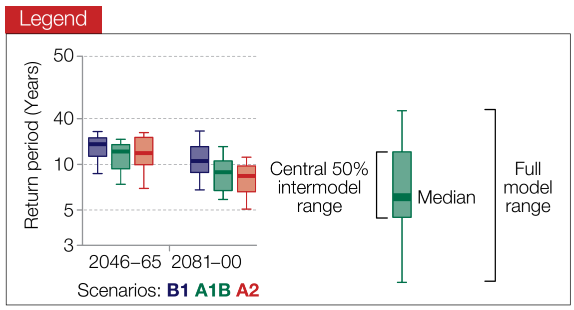
(b) Precipitation

These graphs show how often the wettest day in the last 20 years of the 20th century will be experienced by the middle and end of the 21st century. These are shown under three different emissions scenarios: B1, A1B and A2.[64] For example, in East Asia and the Tibetan Plateau, the wettest day experienced in the last 20 years at the end of the 20th century will happen more like every ten years by the end of the 21st Century depending on which emissions scenario is followed.





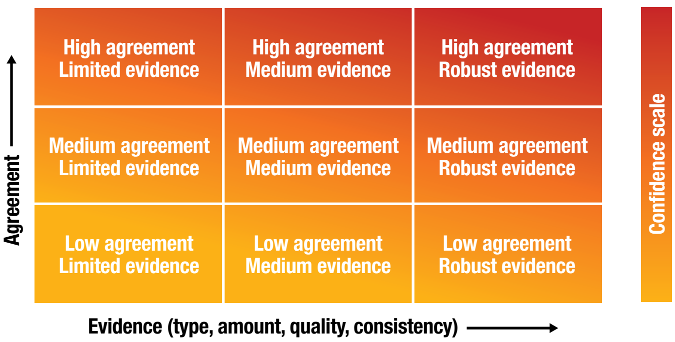




64. These refer to three of the six possible IPCC emissions scenario groups used throughout their reports.
B1 describes a convergent world with rapid changes towards a service and information economy and introduction of clean and resource efficient technologies.
A1B describes rapid economic development and growth, with balanced technological development across all sources. i.e. neither fossil intensive nor all non-fossil sources.
A2 is a heterogeneous world with self reliance and local identity, regional economic development, fragmented and slower growth.
See www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf Figure 1 for more information.

Annex IV: IPCC uncertainty guidance

The standard terms used to define levels of confidence in this report are as given in the IPCC SREX uncertainty guidance note, namely:



The standard terms used in this report to define the likelihood of an outcome or result where this can be estimated probabilistically are:

Term[65]	Likelihood of the outcome
Virtually certain	99 to 100% probability
Very likely	90 to 100% probability
Likely	66 to 100% probability
About as likely as not	33 to 66% probability
Unlikely	0 to 33% probability
Very unlikely	0 to 10% probability
Exceptionally unlikely	0 to 1% probability

65. Additional terms that were used in limited circumstances in the Fourth Assessment Report (extremely likely: 95 to 100% probability, more likely than not: >50 to 100% probability, and extremely unlikely: 0 to 5% probability) may also be used when appropriate.

Annex V: IPCC SREX glossary of terms

Core concepts defined in SREX and used throughout the summary include:

Climate change: A change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate extreme (extreme weather or climate event): The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes.' The full definition is provided in Section 3.1.2 of SREX.

Exposure: The presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected.

Disaster: Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

Disaster risk: The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs, and that may require external support for recovery.

Disaster risk management: Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster DRR, and transfer and promote continuous improvement in disaster preparedness, response and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, resilience, and sustainable development.

Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

Transformation: The altering of fundamental attributes of a system (including value systems, regulatory, legislative, or bureaucratic regimes, financial institutions, and technological or biological systems).

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